GUIDED IMPACT FUSION

MANAGEMENT SUMMARY

v1.1

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ABSTRACT

Igniting inertial confinement fusion should not be difficult in principle: the energy of a hand grenade needs to be injected into a volume of space the size of a raindrop, in the time it takes light to cross a room. However, achieving this with lasers has turned out to be very challenging.

A better method uses the kinetic energy of pellets fired from a linear accelerator. The accelerator is situated a kilometre or more from the fusion site, and fires a graduated-speed train of pellets into a vacuum pipe connecting the two, the later ones travelling faster.

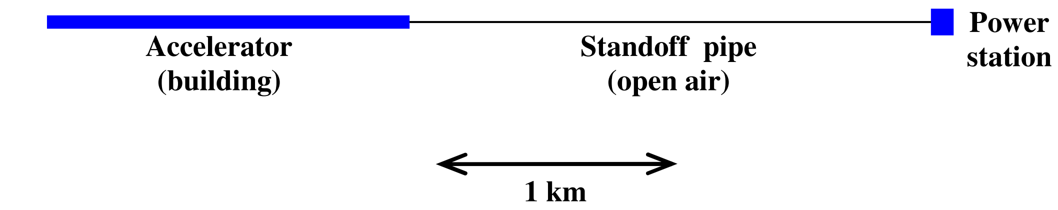
The course of each pellet is individually monitored and corrected several times during flight, so that all catch up together in a precisely specified pattern as they approach the target. The pellets are progressively discharged by electron beams as successively finer course corrections are applied, so mutual repulsion as they converge is never excessive.

The pellet cloud strikes a foil capping a hohlraum to produce a time-tailored pulse of X-rays which implode a fuel capsule: just as planned for laser-driven fusion, but at far lower cost per joule input, with higher energy available if needed, and detonation taking place completely surrounded by a lithium waterfall within a compact chamber.

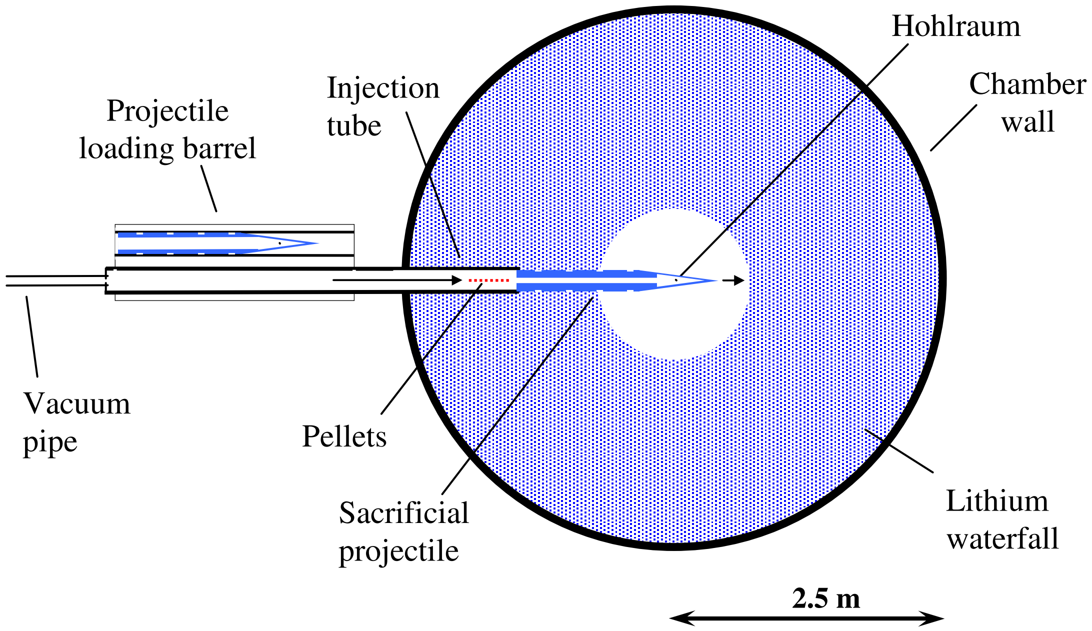
Power station capital cost will be similar to that of a coal-fired unit, with accelerator cost <10% of the total. Fuel cost will be negligible.

Key details are summarized in the following pages. A full paper is at
http://colinbrucescience.files.wordpress.com/2012/02/GIF1.pdf

Accelerator system



Reaction chamber



Hohlraum

DESIGN FEATURES

- A linear accelerator of relatively modest power can be used. An initially long train of pellets fired over a period of a millisecond catch up together in transit to arrive within a span of nanoseconds, greatly multiplying the peak input power rate.
- The distribution and timing of pellets striking the hohlraum foil can be set with high precision, independent of the distance between accelerator and target. Steering accuracy is sufficient to avoid premature inter-pellet collisions.
- The long flight time allows the pellets to be discharged by electron beams in stages after each progressively smaller course correction: mutual repulsion as they converge is avoided.
- Standoff is achieved with an inexpensive pipe, which contains a modest grade of vacuum compared to that required in a fundamental particle accelerator. If the pipe is given a radius of a few centimetres, comparable deviations due to earth movement and wind can be tolerated: the pipe can be mounted in open air.
- A vacuum chamber is not required for the fusion. Detonation takes place within a sacrificial projectile which has been fired into a chamber containing a lithium waterfall.
- Almost all neutrons and kinetic energy are absorbed to heat the lithium: virtually none reaches the chamber wall, which has indefinite working life. Energy is extracted by circulating the lithium through a heat exchanger using electromagnetic pumps.
- All tritium required is produced in the lithium. High energy neutrons interacting with ^{7}Li can generate both tritium and a second neutron, so the fuel cycle can be closed with less than 100% capture efficiency.
- The scaling laws to reach higher ignition energies are favourable. Even if a very large ignition pulse turns out to be required, it can be provided.

KEY ENABLING TECHNOLOGIES

- Operating at modest frequency compared to a particle accelerator, the pellet accelerator can be powered by cheap solid state MOSFETs, providing variable frequency RF power at ~150 MHz.
- Accelerator tube is similar to the 'dielectric wall' design currently under development at Los Alamos for medical use, which can produce gradient > 100 kV/mm.
- Los Alamos have demonstrated that a modified particle accelerator can fire a continuous stream of micropellets even from an impure source without performance degradation: a chicane weeds out pellets whose charge/mass ratio is outside tolerance.
- Inexpensive induced voltage sensors measure the position and timing of each pellet as it passes along the beamline: 12-bit ADCs operating at > 3 GHz are COTS-available.
- Small numbers of rapidly switchable electrode pairs along the beamline tweak the pellet trajectories: solid state power switches operating at >20 GHz are COTS-available.
- Fuel capsule design is identical to that already developed for laser-driven fusion.
- Even more accurate pellet positioning could be done if required. With picosecond pulse lasers providing exposure control, cheap CCD or CMOS cameras can photograph passing pellets to ~1μm precision. With some on-chip preprocessing (a slightly more sophisticated version of pixel binning) to reduce data volume transferred, each camera can report the position of hundreds of pellets per pulse.

DEVELOPMENT

An electricity generating station in the gigawatt range will have a capital cost similar to a coal-fired unit: the accelerator represents only ~10% of new build cost. It will also be possible to retrofit most existing coal-fired stations to use fusion. Fuel cost will be negligible. Power generated will be cheaper than from any other source.

R & D required is modest. The technology of linear accelerators, including the modifications required to fire charged pellets, is mature. All components required for pellet tracking and steering are COTS-available. The expertise necessary for development, electrical engineering closely related to particle accelerator design, is widely available.

It is helpful that there are no military applications: the system is too long to fit aboard any vehicle, even a large oceangoing vessel, and incapable of detonating anything larger than a fuel capsule. Simpler ways to manufacture neutrons and tritium exist.

Full IP protection will be available during development. 24 of 29 claims of patent PCT/GB2011/000009, describing the apparatus and methods herein with a base priority date of 4th January 2010, have been accepted by the international examiner.

There is an enormous margin, two orders of magnitude, between the input energy estimated to be needed and the maximum which could be delivered by the accelerator if necessary. In stark contrast to every other fusion system proposed to date, technical risk is close to zero.

QUANTITATIVE DETAILS

The following numbers can be checked on the back of an envelope by anyone with high school physics and access to Google.

Pellets of Weldalite 049-T8 aluminium-lithium alloy 40 μm in diameter are charged to 200 kV to carry charge 0.44 nC: burst-apart force is 2/3 of their yield strength. They are accelerated to speeds ranging from 630-770 km/sec in a 60 GV AC accelerator whose electrodes are driven at 126-154 MHz by RF power MOSFETs whose cost is ~$3/J pulse: four parallel tubes fire 90,000 pellets each

The pellets catch up together as they fly down a 2.25 km vacuum pipe. Their exact positions are measured at intervals using ADCs connected to small conducting loops, which have voltage induced in them as the charged pellets pass. Their trajectories are then corrected by electrodes driven by solid state switches.

The pellet cloud strikes a membrane which caps a hohlraum. The membrane material has lower average atomic mass than the pellets, so most of the X-rays emitted go forward into the hohlraum.

A fuel capsule within the hohlraum is heated in a bath of X-rays identical to that experienced within a laser-driven hohlraum. 8 MJ of pellet kinetic energy delivers 1 MJ of X-rays to a 4.1 mm diameter hollow-sphere capsule, which implodes to yield 200 MJ fusion energy, as planned for LIFE.

The hohlraum is at the front of a hollow sacrificial projectile which has been fired into a 5 m diameter containment chamber. 100 tonnes of liquid lithium, circulating as a 'waterfall' through the chamber and subsequently a heat exchanger, absorb effectively all of the neutrons and energy output, breeding exactly as much tritium as was consumed in the shot, and producing an additional 40 MJ energy from induced fission.

Fuel cost will be negligible: 200g deuterium (from heavy water) and 600g lithium-6 are consumed daily to produce 1 GW net electric output.

Further details are in the paper at
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